# The Effect of Battery Type and Ambient Temperature on the Operation of Warning Flashers

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## PREFACE

The aim of the present Report is to provide basic information for both manufacturers and users of battery-operated warning flashers mainly concerning how battery costs can be reduced and how the costs associated with the use of different types of battery can be compared. Particular attention has been given to the effect of low temperatures.

The Report is based on investigations and measurements /1/, /2/, /3/, /4/, /5/ commissioned by the Technical Development Centre of the Finnish Roads Administration and carried out under the leadership of Professor Juhani Kärnä in the Laboratory of Lighting Technology of the Department of Electrical Engineering at Tampere University of Technology. The practical research work was carried out by Tapani Nurmi, research engineer. On behalf of the Finnish Roads Administration the work was supervised by Esko Hyytiäinen, M.Sc. (Eng.) and Esko Tuhola, B.Sc. (Eng.)

## CONTENTS

# 1 INTRODUCTION

Because batteries still seem to be holding on to their key position as a source of power for warning flashers and lanterns, it has been considered necessary to produce a summary mainly of the basic facts which are significant in relation to the amount of energy utilized from the batteries of warning flashers and the choice of battery from both the tecnical and economic point of view.

In addition to the basic photometric concepts /1/ and the guality requirements /7/, which are not dealt with in this Report, a basic knowledge of the working principles of battery-operated flashers is essential. Particular attention must be given to the effect of the voltage losses arising from internal resistance in both the battery and the mechanism and on the concept of the "end voltage" of the battery.

It is not possible to estimate battery costs or to make a technical / economic comparison between batteries without a knowledge of the behaviour of the battery used in a flasher in different operating temperatures. The most important characteristics are the change in the voltage available at the battery terminals as a function of the load period and the relation between the energy taken from the battery and the voltage at the battery terminals. Because in Finland this data is not measured in connection with the test measurements made on flashers, in this Report use has been made of graphs taken from sources /2/ and /3/. It should be particularly noted that the ampere-hour figures diven by battery manufacturers are not applicable for this purpose, since they differ appreciably from conditions of flasher use in respect of both manner of loading and temperature.

# 2 BATTERY OPERATED WARNING FLASHERS

## 2.1 Working Principle

The construction of a battery-operated warning flasher fitted with a filament lamp bulb is shown schematically in Figure 1. The voltage at the battery terminals is denoted by $u_p$, the current drawn from the battery by $i_p$ the lamp voltage by $u_L$ and the lamp current by $i_L$. The lamp voltage generally consists of voltage.

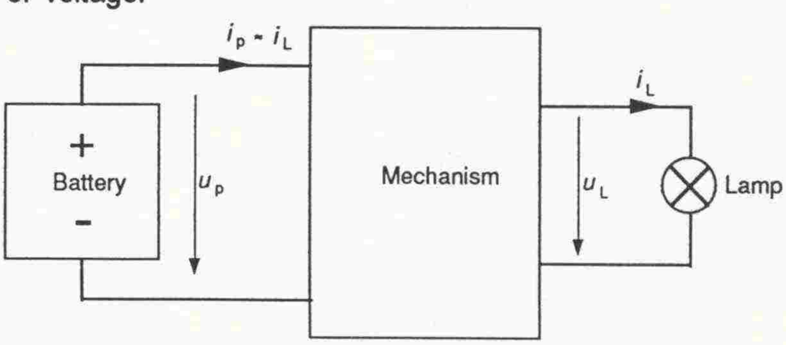



Figure 1: Schematic construction of a battery-operated warning flasher.

pulses at the operating frequency of the flasher, the amplitude of these pulses being the voltage at the battery terminals less the losses arising in the mechanism and the length of the pulses being constant. As a consequence of the internal resistance of the battery the voltage ($u_p$) at the battery terminals is not constant.

Every time the lamp receives a voltage pulse a current pulse $i_p$ is drawn from the battery which is approximately equal to the current pulse $i_L$ going to the lamp. This causes a voltage drop through the internal resistance of the battery thereby reducing $u_p$.

The mechanism in its construstion may also be of the so-called constant luminous intensity type, which as indicated by its name attempts to maintain the effective luminous intensity /4/ of the flash constant independent of the voltage at the battery terminals. This can be achieved either by making the length of the voltage pulse which is fed to the lamp depend in a suitable way on the voltage at the battery terminals, or else by making the magnitude of the arithmetic mean of the voltage pulse fed to the lamp independent of the voltage at the battery terminals by means of using a switching stabilization unit.

## 2.2 Relation between luminous intensity and voltage of lamp

The luminous intensity of a warning flasher fitted with a filament lamp is very strongly dependent on the battery voltage. This is ilustrated in Figure 2, which shows the relation between the luminous intensity and voltage. The unit of measurement used for the luminous intensity is the value of the luminous intensity at the rated voltage.

From the figure it can be seen that a drop in the voltage by 10 % from the rated voltage causes the luminous intensity to fall by apporox. 70 %. Correspondingly, a 10 % over-voltage increases the luminous intensity almost 1.4 times.

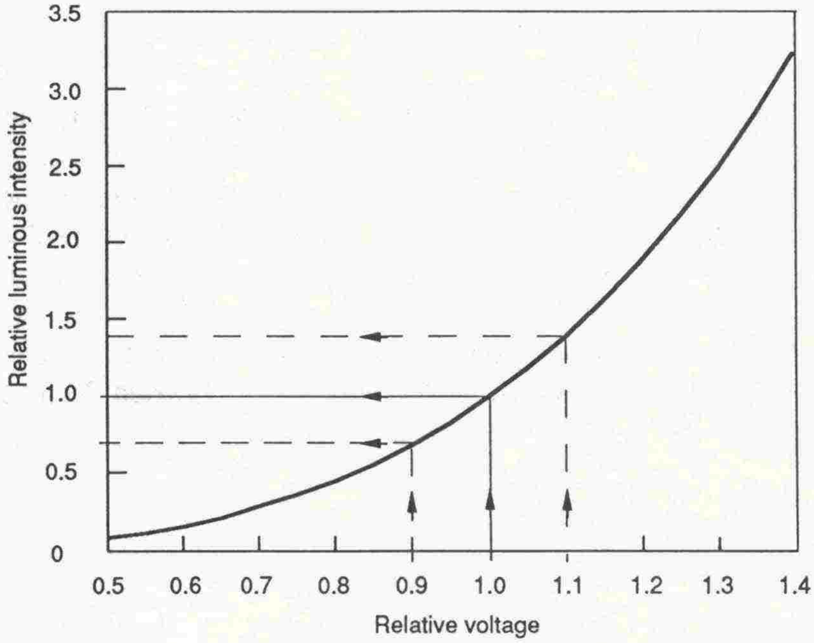



Figure 2: Relation between the luminous intensity of a filament lamp and the voltage.

## 2.3 Change in Voltage Available from Battery during Use

In principle the voltage at the terminals of the battery falls during the period of operation in the manner shown in Figure 3. Generally three separate regions, Region I, Region II and Region III, can be seen. In Region I, which usually lasts for not more than a few days, the voltage falls rapidly. In Region II the fall in the voltage at the terminals becomes considerably slower. When the energy of the battery is nearly exhausted the voltage at the terminals again falls rapidly. This is Region III.

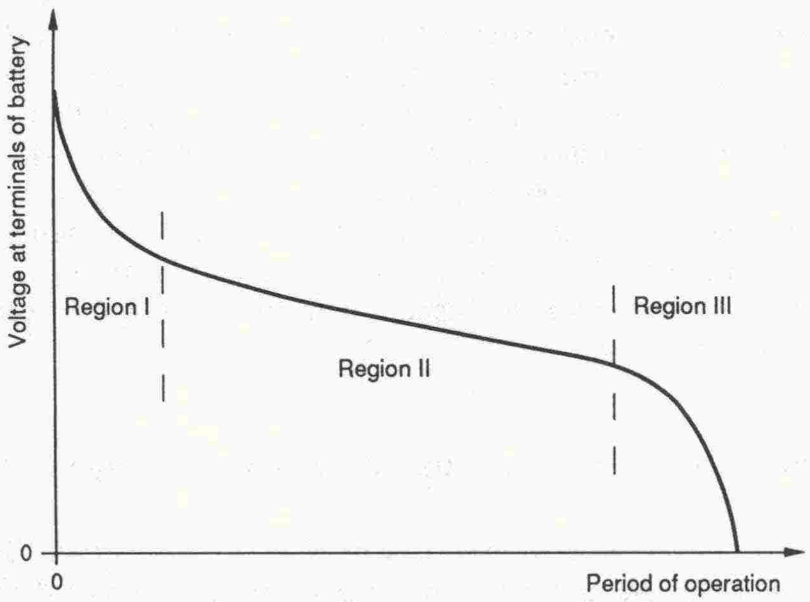



Figure 3: Relation between voltage at the terminals of the battery and the period of operation.

At the same time as the battery voltage falls, the luminous intensity of the flasher also falls, unless the flasher has a so-called constant luminous intensity mechanism.

## 2.4 End Voltage of Battery

Regardless of what type of mechanism is used by the flasher, there is always some value of voltage at the battery terminals, the so-called end voltage, below which the photometric values of the light signal no longer satisfy the requirements of the regulations. In order to determine the end voltage it is necessary to measure the luminous intensity of the flasher in accordance with the quality requirements /6/ as a function of voltage at the battery terminals. Depending on the working principle of the mechanism of the flasher, graphs such as those in Figure 4 are obtained. In a flasher without.

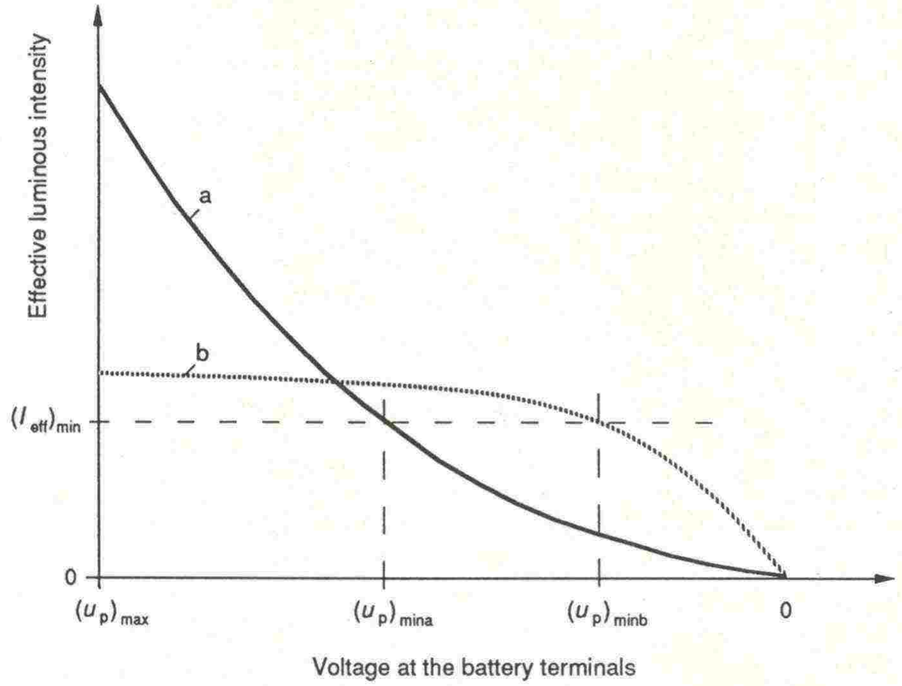



Figure 4: Relation between the effective luminous intensity of a flasher and the voltage at the battery terminals
a) for a flasher with conventional mechanism
b) for a flasher fitted with a constant luminous intensity mechanism.
$(I_{eff})$min is the nimimum permitted luminous intensity
$(U_p)$mina is the so-called end voltage, case a
$(U_p)$minb is the so-called end voltage, case b

a mechanism for regulating the luminous intensity, the luminous intensity is generally strongly dependent on the voltage at the battery terminals. In a flasher with constant luminous intensity mechanism appreciable fall in the luminous intensity generally occurs only at low values of the voltage at the battery terminals.

When the minimum of luminous intensity $(I_{eff})$min marked on the luminous intensity axis of the graphs in Figure 4, the value of the end voltage $(U_p)$min can be obtained from the votage axis.

## 2.5 Energy of Battery in Flasher Use

The relation between the energy (E) used by the flasher and the voltage $(U_p)$ at the battery terminals is shown in Figure 5. Emax is the energy available from the battery in conditions corresponding to flasher use and $(U_p)$max is the voltage at terminals of a new battery.

At first the voltage at the terminals of the battery falls rapidly, although the amount of energy taken from the battery remains small. This corresponds to Region I of the curve in Figure 3. After this energy can be drawn from the battery with only a moderate fall in the voltage at the terminals. This corresponds to Region II of the curve in Figure 3. Towards the end of the curve the changes in the voltage at the terminals are large even though very little energy is drawn from the battery. This corresponds to Region III of the curve in Figure 3.

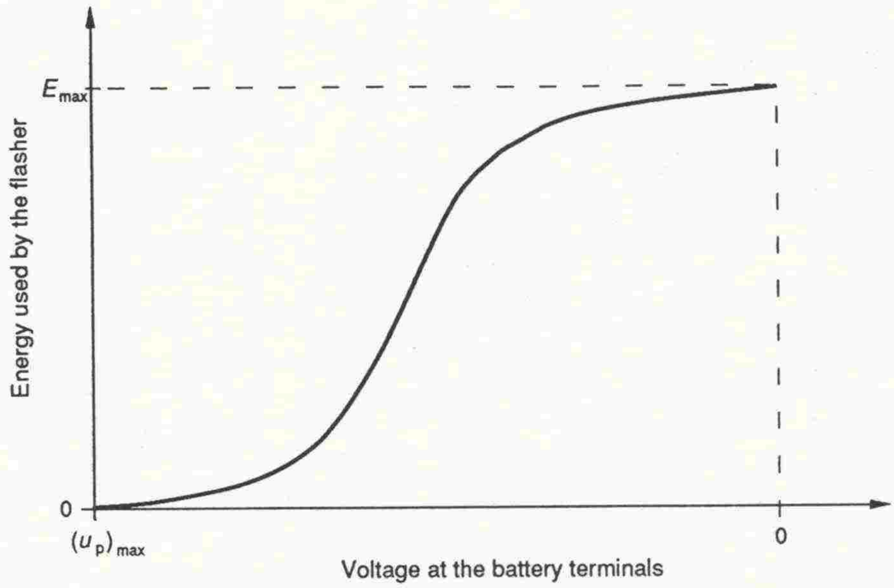



Figure 5: Relation between the energy taken from the battery and the voltage at the battery terminals.

# 3 MEASUREMENTS

In Appendices 1...18 the variation of the voltage at the battery terminals as a function of the load period and also the ampere-hour value as a function of the voltage at the battery terminals are given for different classes and types of battery. Concerning the graphs it can be noted that:

- the measurements are made at temperatures of +5°C, -10°C and -20°C /2/, /3/
- the graphs shown are graphs of the averages of several measurements
- in performing the load tests the load periods have been chosen in accordance with the quality requirements for warning flashers currently in force in Finland /7/ (16h on, 8h off).
- the load tests were not carried out with real flashers but on the basis of the electrical values of the lamps used in flashers a load resistor was determined for each type of battery which corresponded as well as possible to the lamp suitable for that type of battery.
- the frequency of the current pulses was 1 Hz and the duration of the current pulses was 150 ms.

# 4 EXAMPLE OF THE INTERPRETATION OF MEASUREMENTS

Assume that a flasher has a rated voltage of 6V and it is designed to operated on two IP5 batteries. How long will the flasher operate on Duracell batteries at a temperature of

a) +5°C

b) -20°C.

How would the situation change if AIRAM batteries were used instead?

In solving the question it possible to proceed as follows:

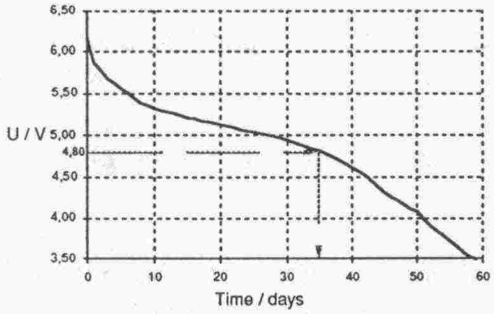
Step 1. Determine the end voltage for the flasher

The end voltage for the warning flasher can be obtained from the report of the official trials performed on the flasher. Where such a test report is not available, the end voltage can be determined in the manner described in Section 2.4.

For the type of warning flasher in question the end voltage is typically about 4.8V /4/.

Step 2. From the Appendices find the measurement results corresponding the case in question and mark the end voltage of the flasher on the graphs.

The graphs corresponding to the case in quuestion are shown in Figures 6 and 7 (Appendices 3,4,15 and 16, and the end voltage 4.8V has also been marked on these.



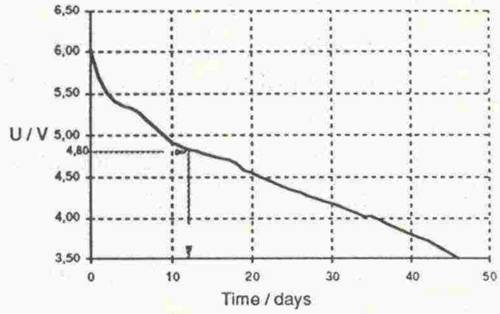
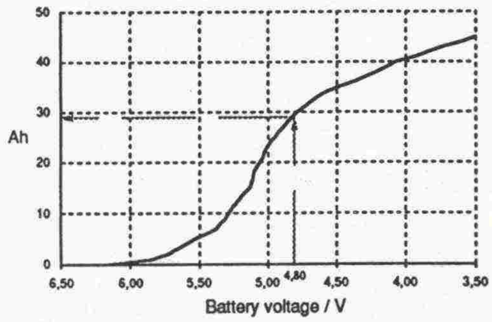




Figure 6: a. Relation between voltage at battery terminals and load period at a temperature of +5°C

b. Relation between voltage at battery terminals and load period at a temperature of -20°C

Step 3. From Figures 6a and 6b it can be seen that the flasher will operate in conformity with the regulations for apporox. 35 days at a temperature of +5°C but only for approx. 12 days at a temperature of -20°C.

From Figures 7a and 7b, on the other hand, it can be seen that approx. 29 Ah are then used from the battery at +5°C and only 10 Ah at a temperature of -20°C.



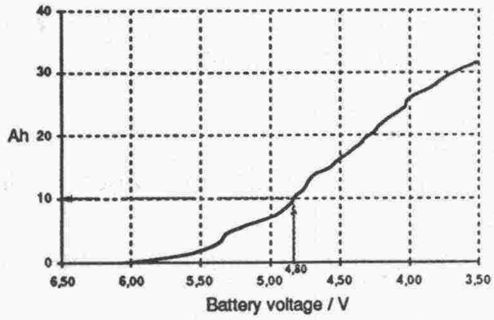




Figure 7: a. Relation between energy used from the battery and the voltage at the battery terminals at a temperature of +5°C
b. Relation between energy from the battery and the voltage at the battery terminals at a temperature of -20°C.

If a similar examination is conducted for AIRAM batteries, then it is possible to compare the two types of battery from the technical point of view. If in addition the price of the batteries is known, then it is possible to calculate the price per usable ampere-hour for each of the batteries.

# 5 CONCLUSIONS

The basic requirements for a good warning flasher are:

- all the light emitted by the flasher should be directed into the region specified by the quality requirements and in the manner specified by the quality requirements
- the light output of the lamp should be as high as possible and the lamp should last as long as the battery.

The end voltage of the flasher should be low so that the energy of the battery can be well utilized.

Because the operation of the flasher no longer conforms to the quality requirements when the voltage at the battery terminals is below the end voltage, this should be visible in some way from the operation of the flasher, e.g. by a change in the frequency of flashing.

If a warning flasher will be required to operate at low temperatures, then particular attention should be given to the choice of batteries.

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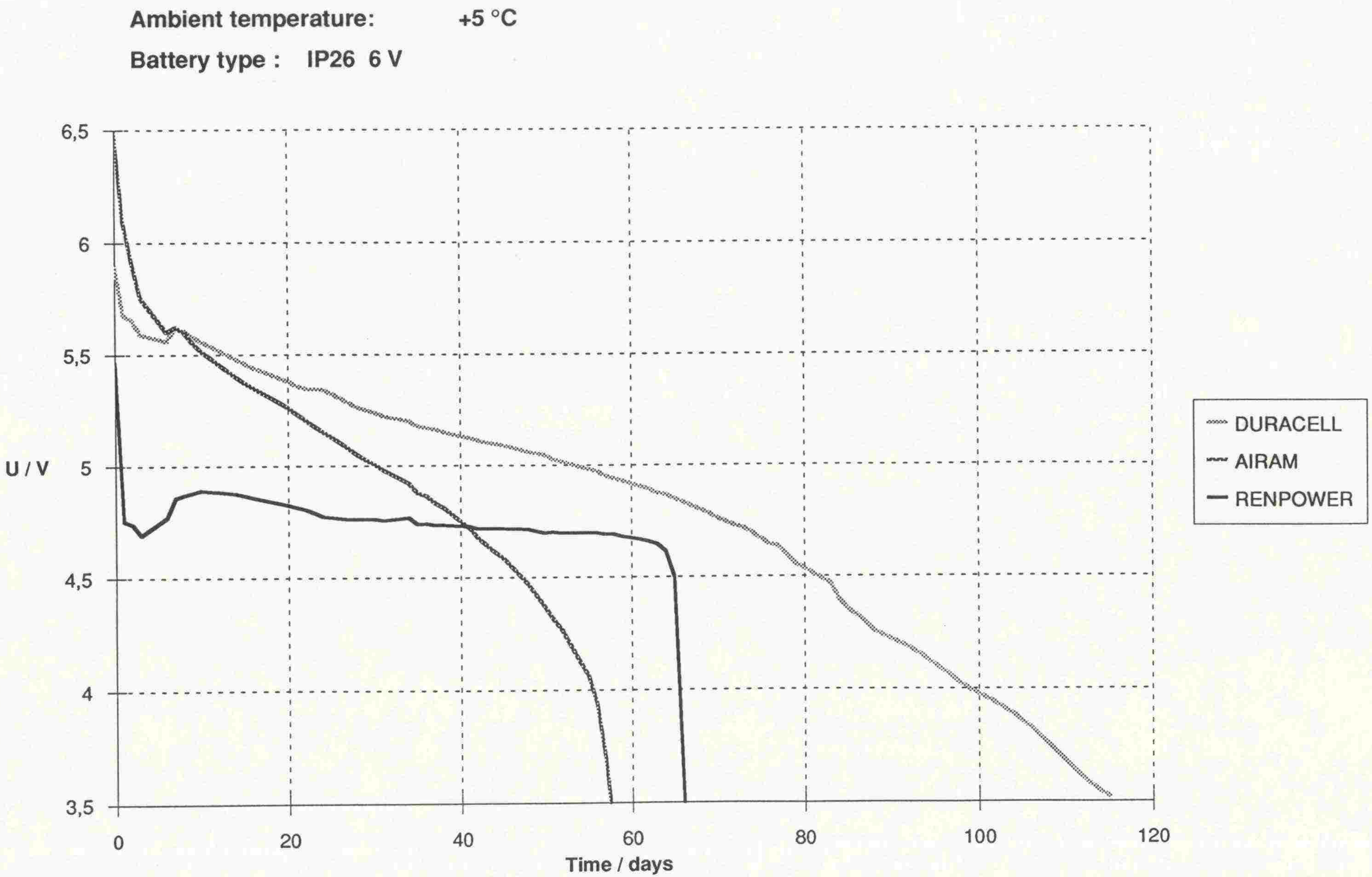
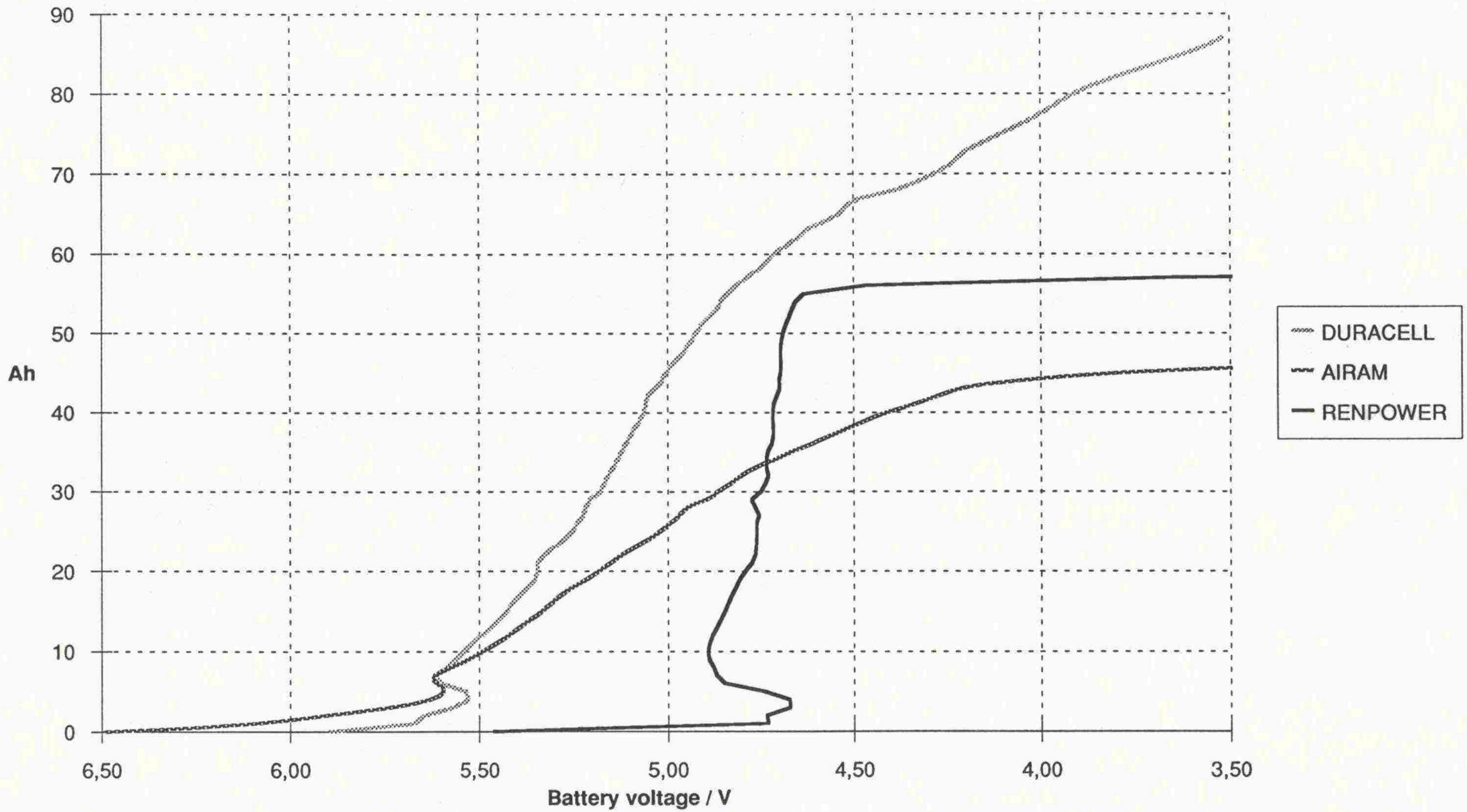

Ambient temperature: +5 °C
Battery type : IP26 6 V
U / V
6,5
6
5,5
5
4,5
4
3,5
0
20
40
60
80
100
120
Time / days
DURACELL
AIRAM
RENPOWER

APPENDIX 2

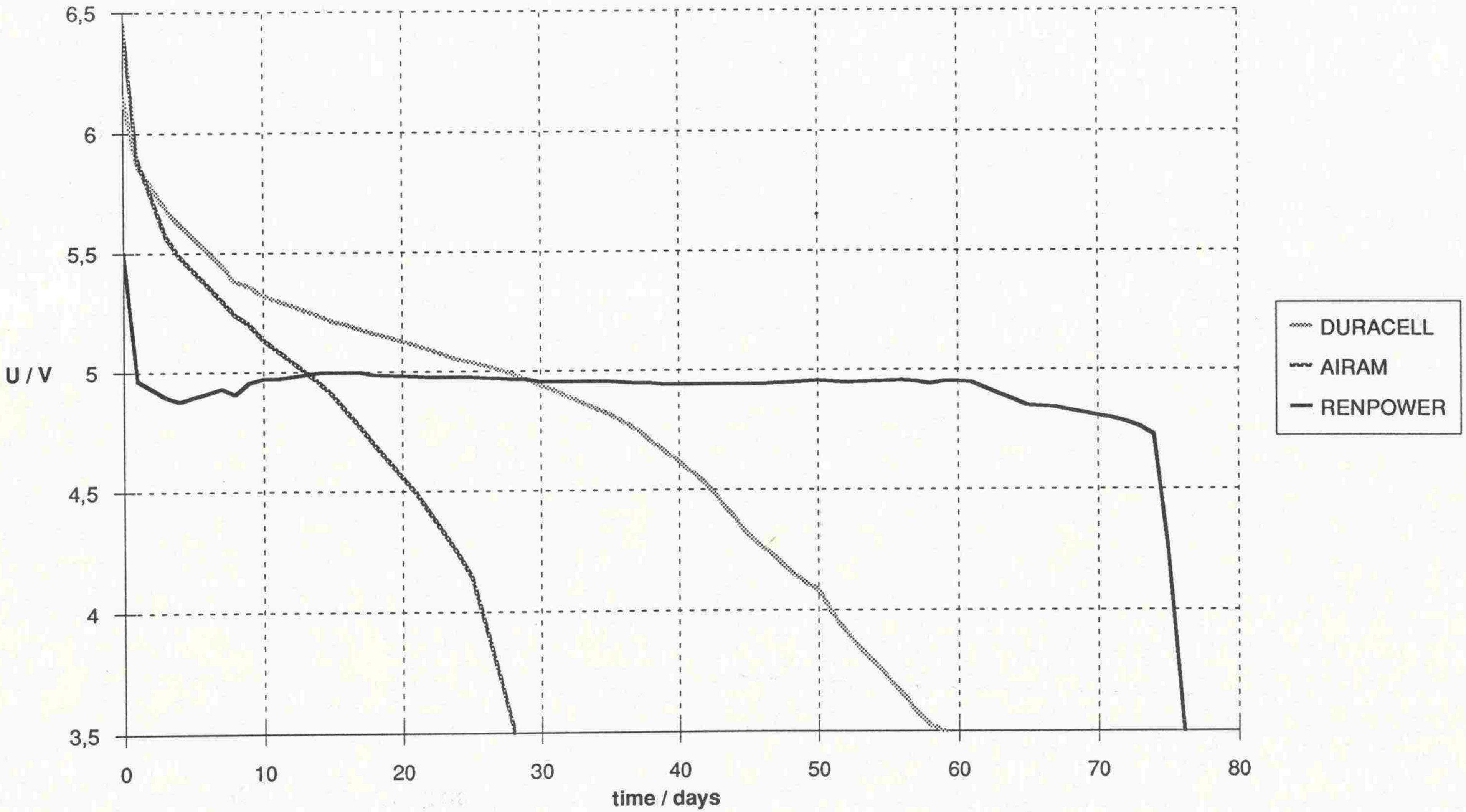
**Ambient temperature: +5 °C**

**Battery type : IP26 6 V**



**Ambient temperature: +5 °C**

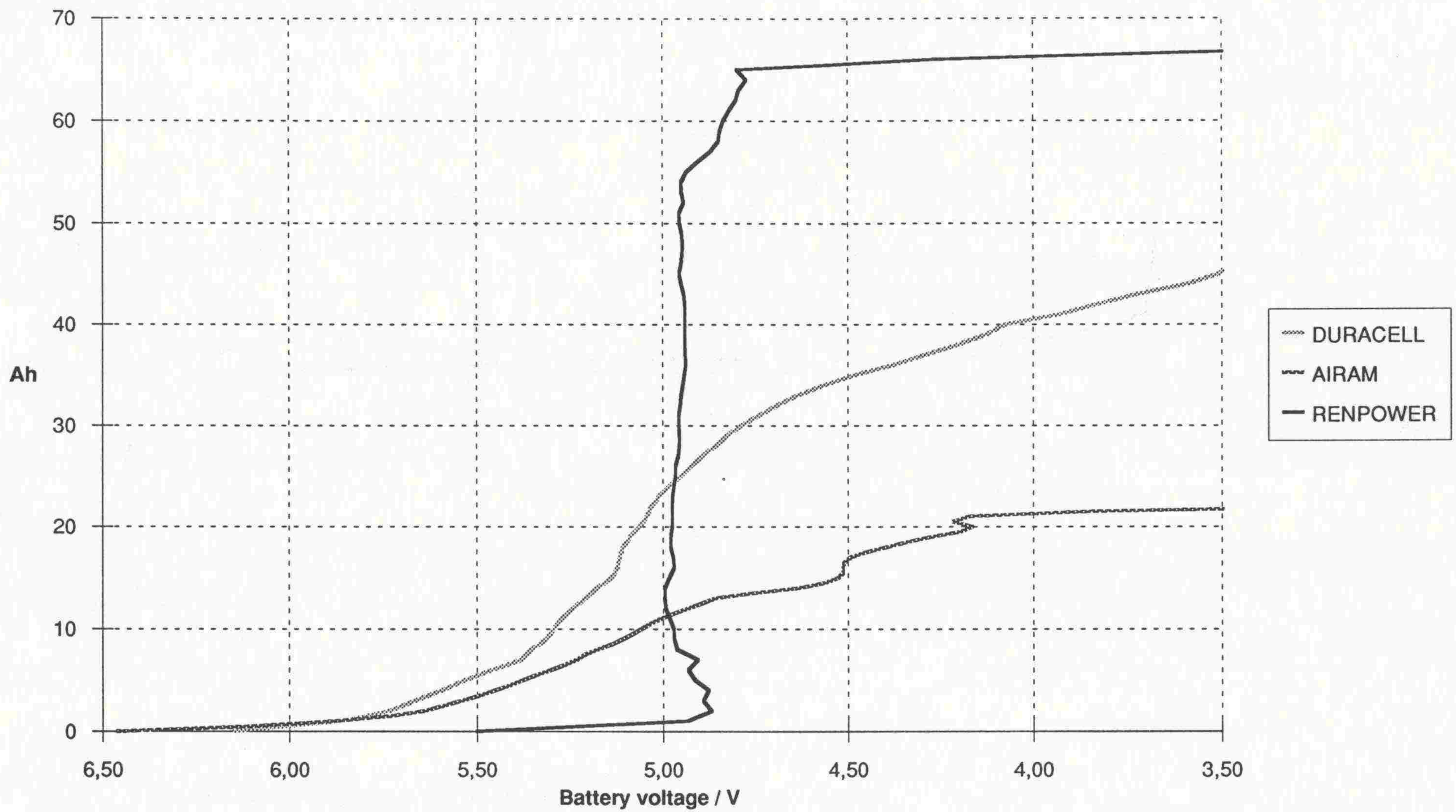
**Battery type : IP5 6 V / 2 parallel**



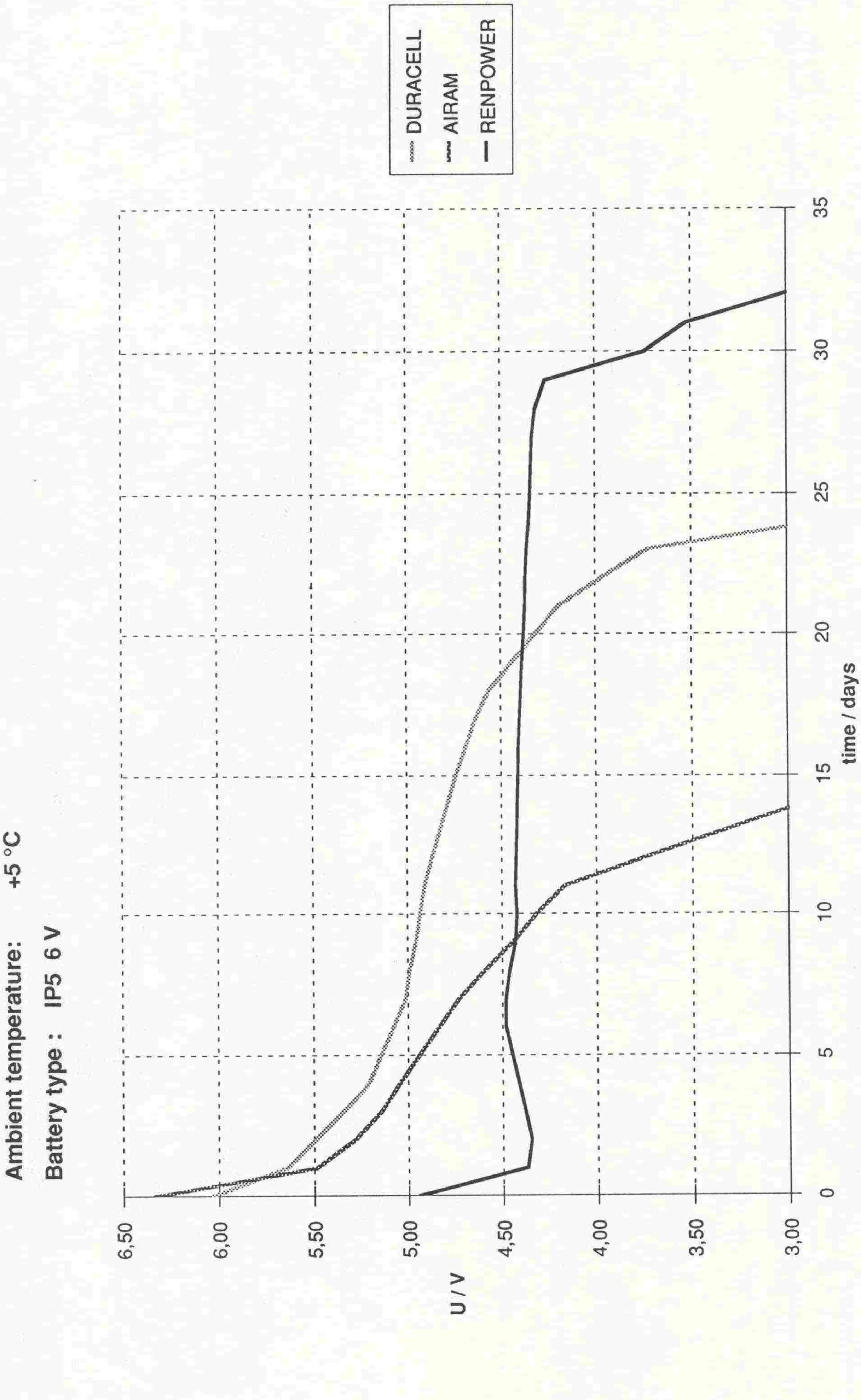
# APPENDIX 4

**Ambient temperature: +5 °C**

**Battery type : IP5 6 V / 2 parallel**



APPENDIX 5

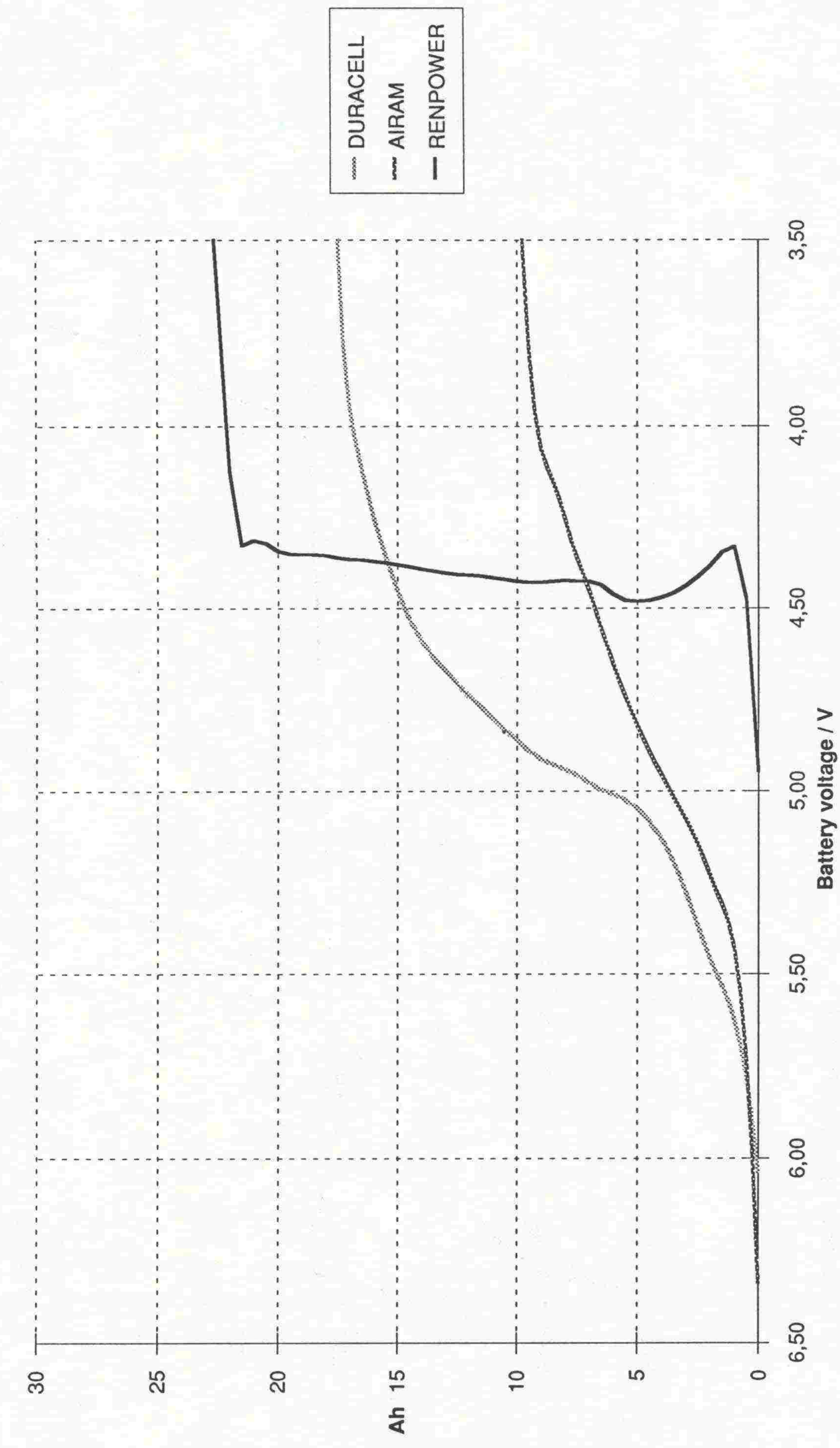


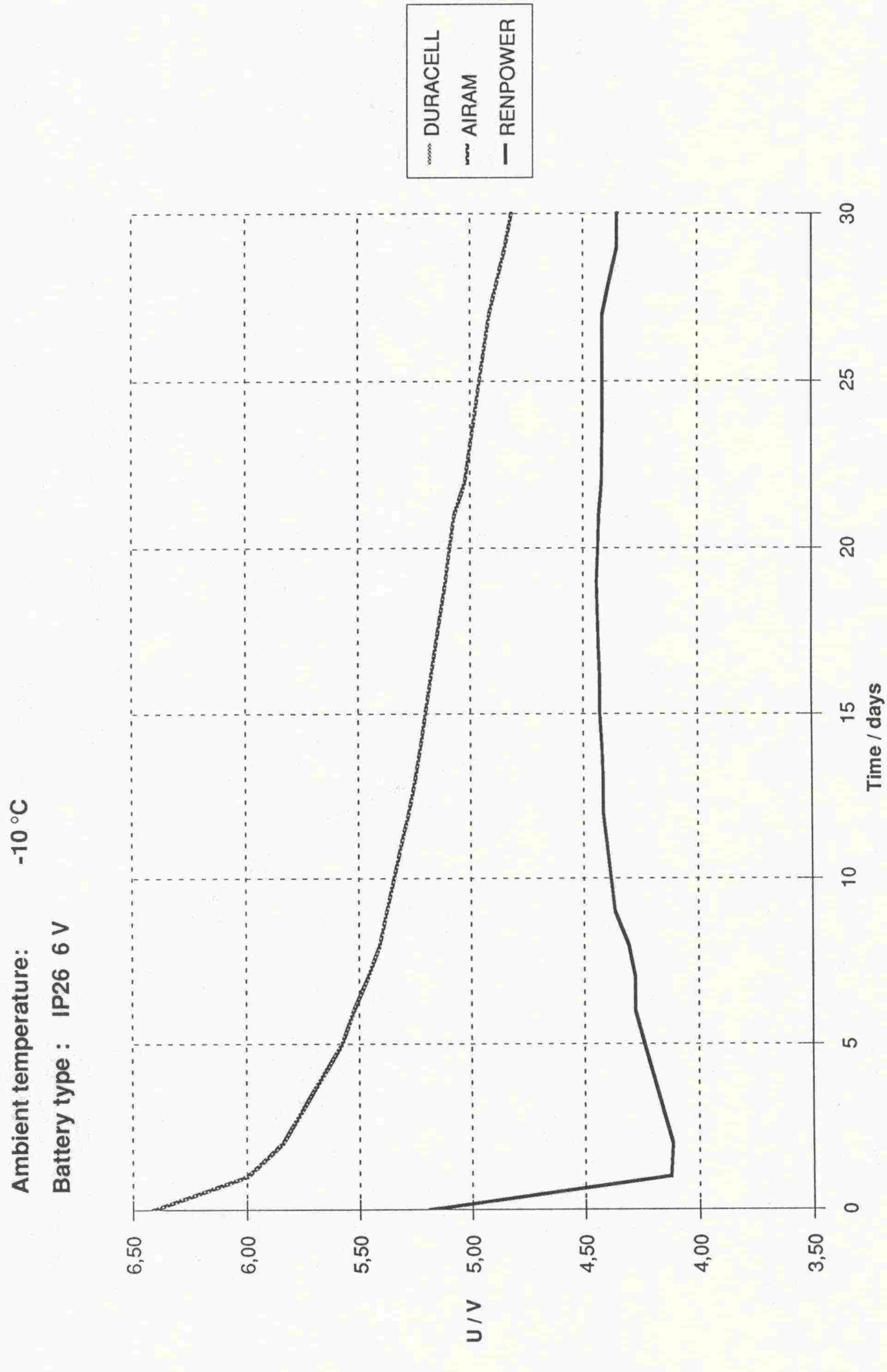
Ambient temperature: +5 °C
Battery type : IP5 6 V
DURACELL
AIRAM
RENPOWER
U / V
6,50
6,00
5,50
5,00
4,50
4,00
3,50
3,00
time / days
0
5
10
15
20
25
30
35

APPENDIX 6

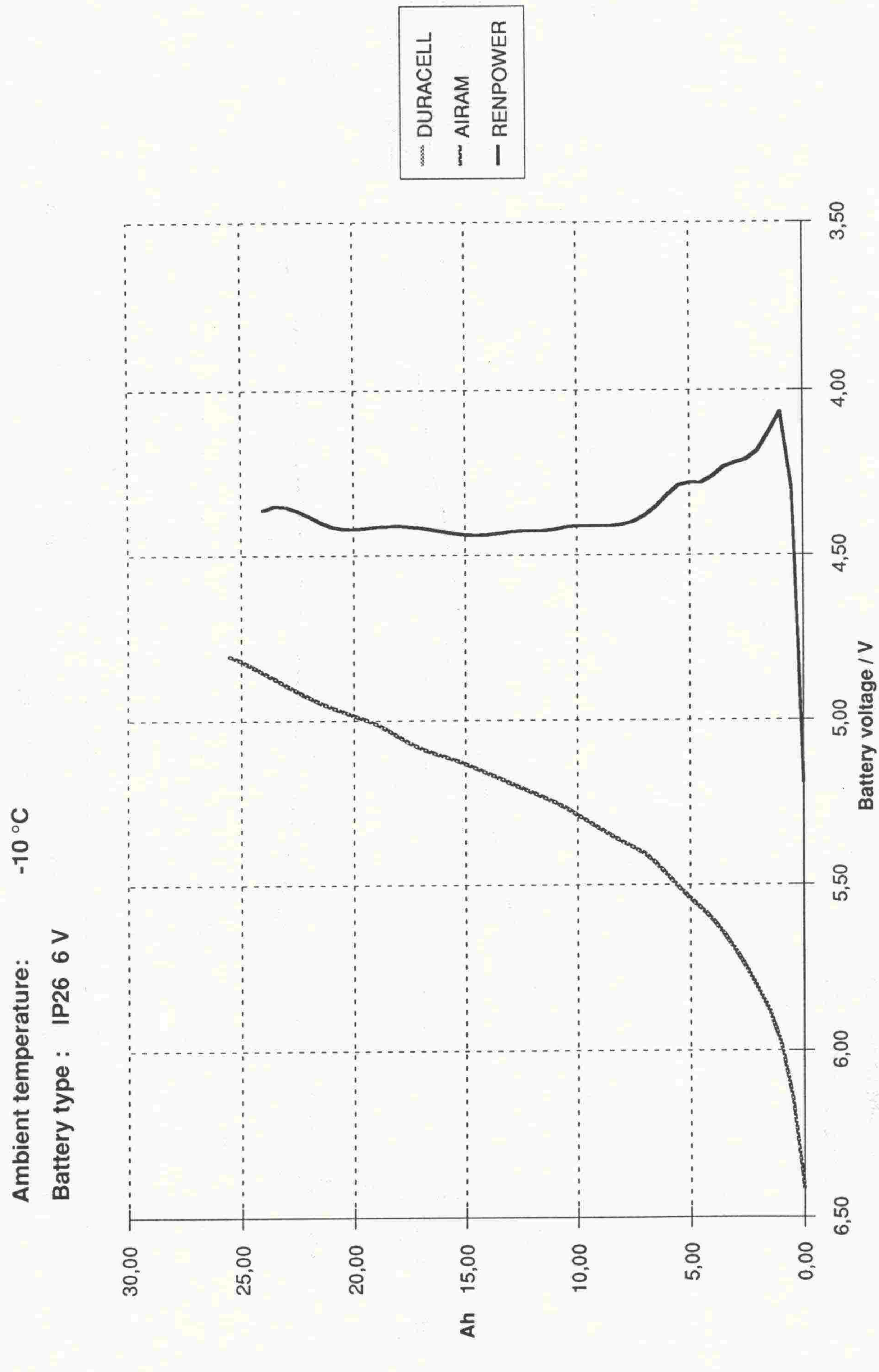
**Ambient temperature: +5 °C**

**Battery type : IP5 6 V**




Ambient temperature: -10 °C
Battery type : IP26 6 V
U / V
6,50
6,00
5,50
5,00
4,50
4,00
3,50
0
5
10
15
20
25
30
Time / days
DURACELL
AIRAM
RENPOWER

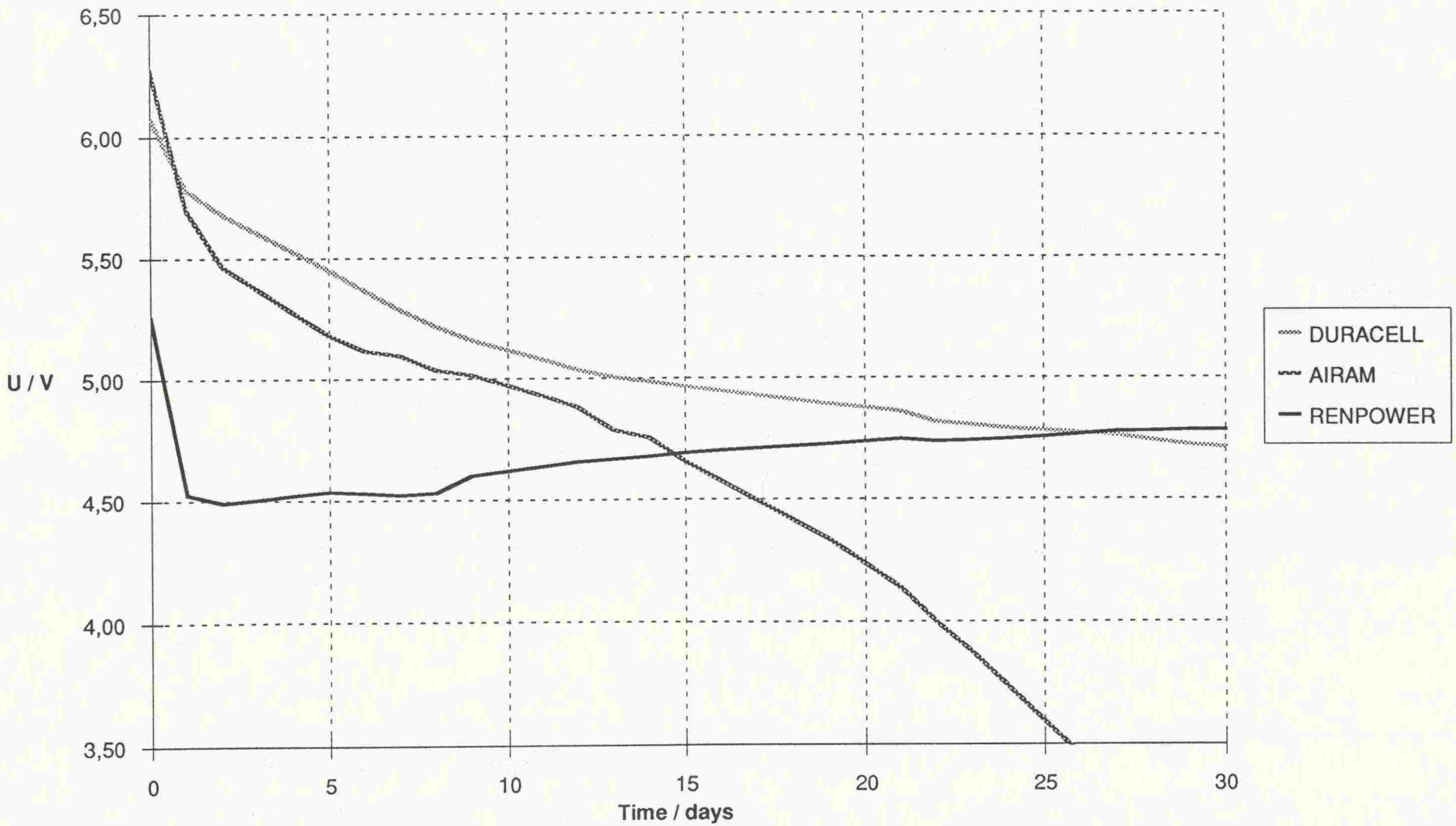
APPENDIX 8



Ambient temperature: -10 °C
Battery type : IP26 6 V
DURACELL
AIRAM
RENPOWER
Ah
30,00
25,00
20,00
15,00
10,00
5,00
0,00
6,50
6,00
5,50
5,00
4,50
4,00
3,50
Battery voltage / V

**Ambient temperature: -10 °C**

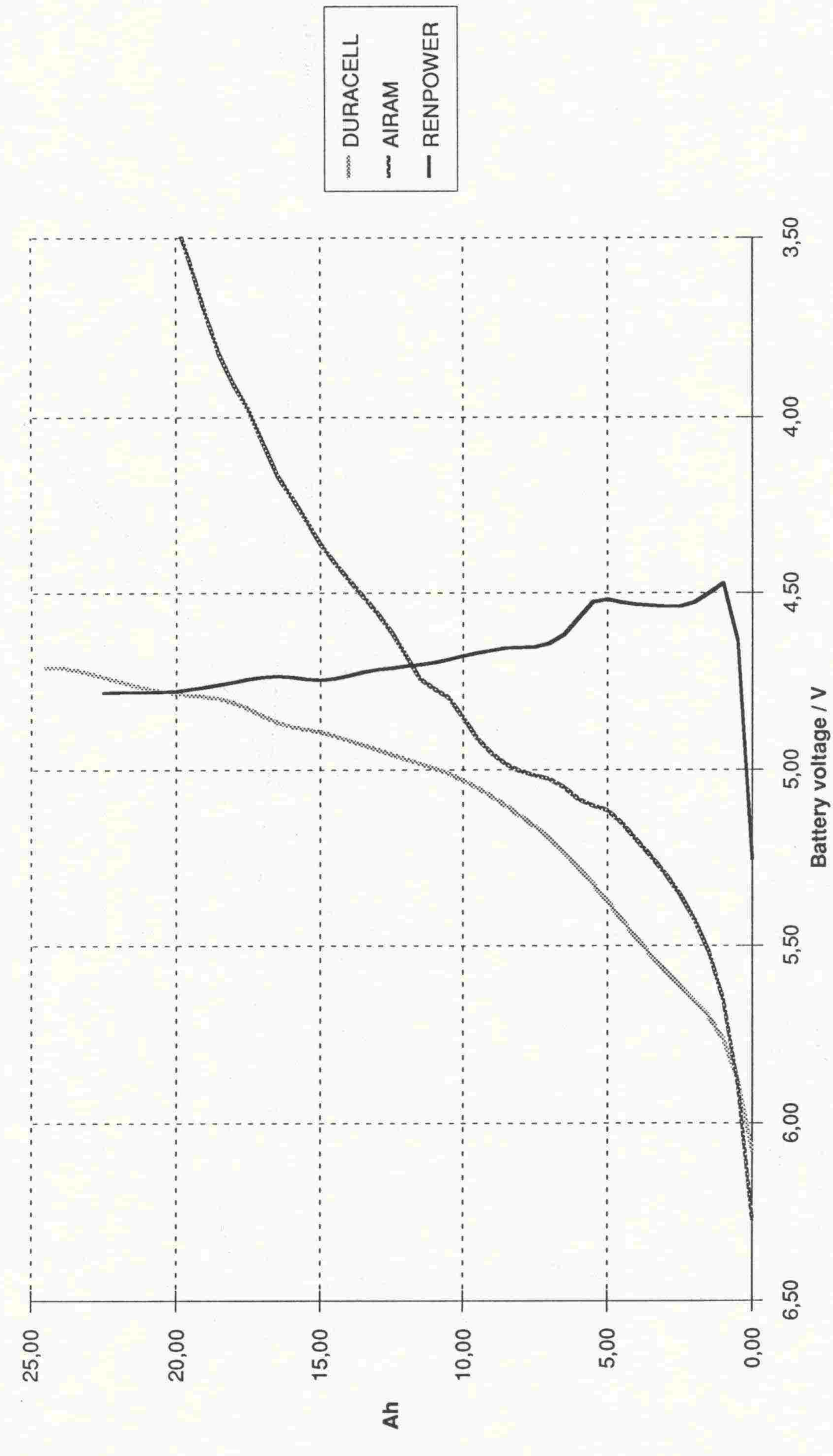
**Battery type : IP5 6 V / 2 parallel**

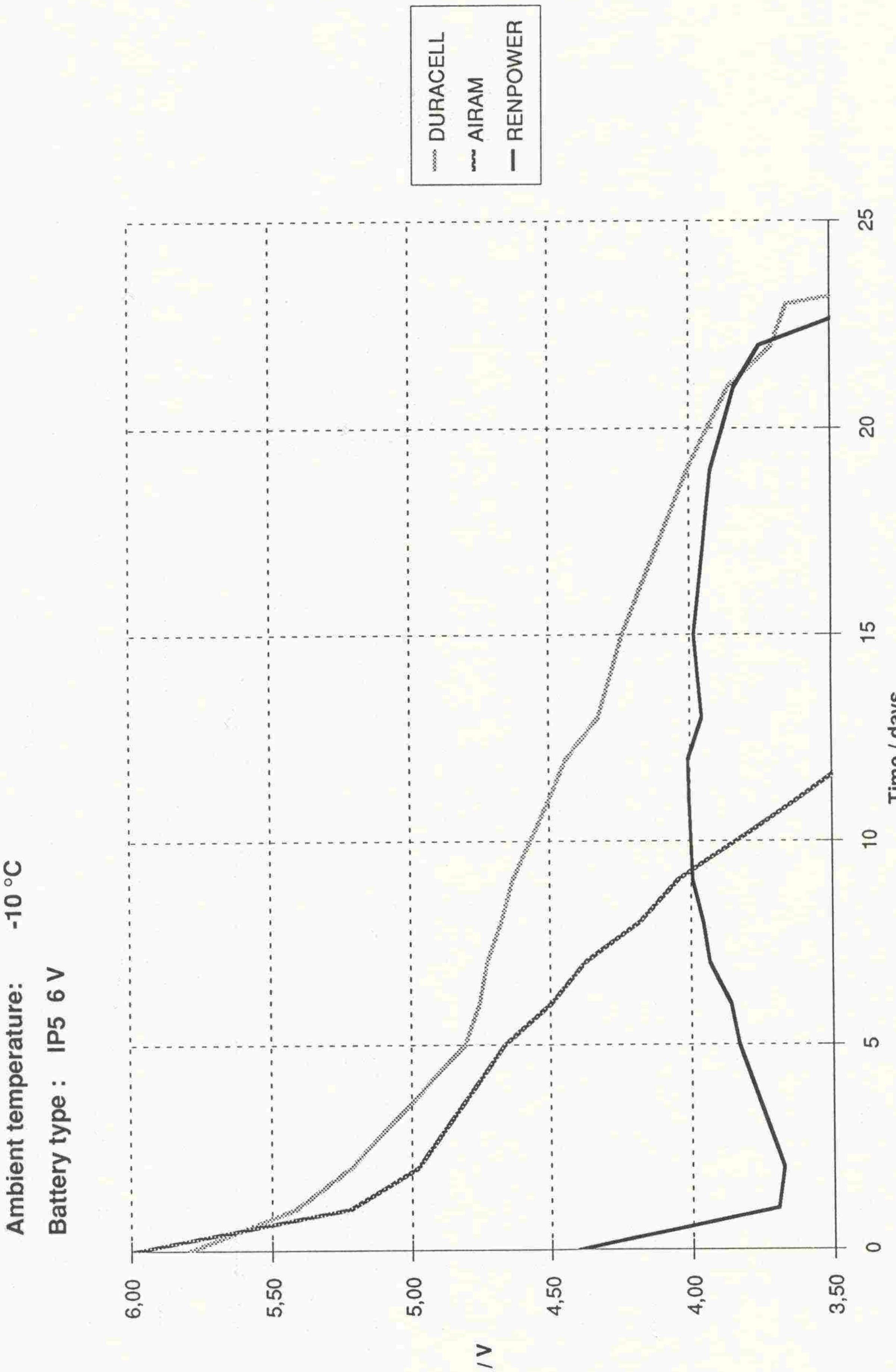


APPENDIX 10

Ambient temperature: -10 °C

Battery type : IP5 6 V / 2 parallel

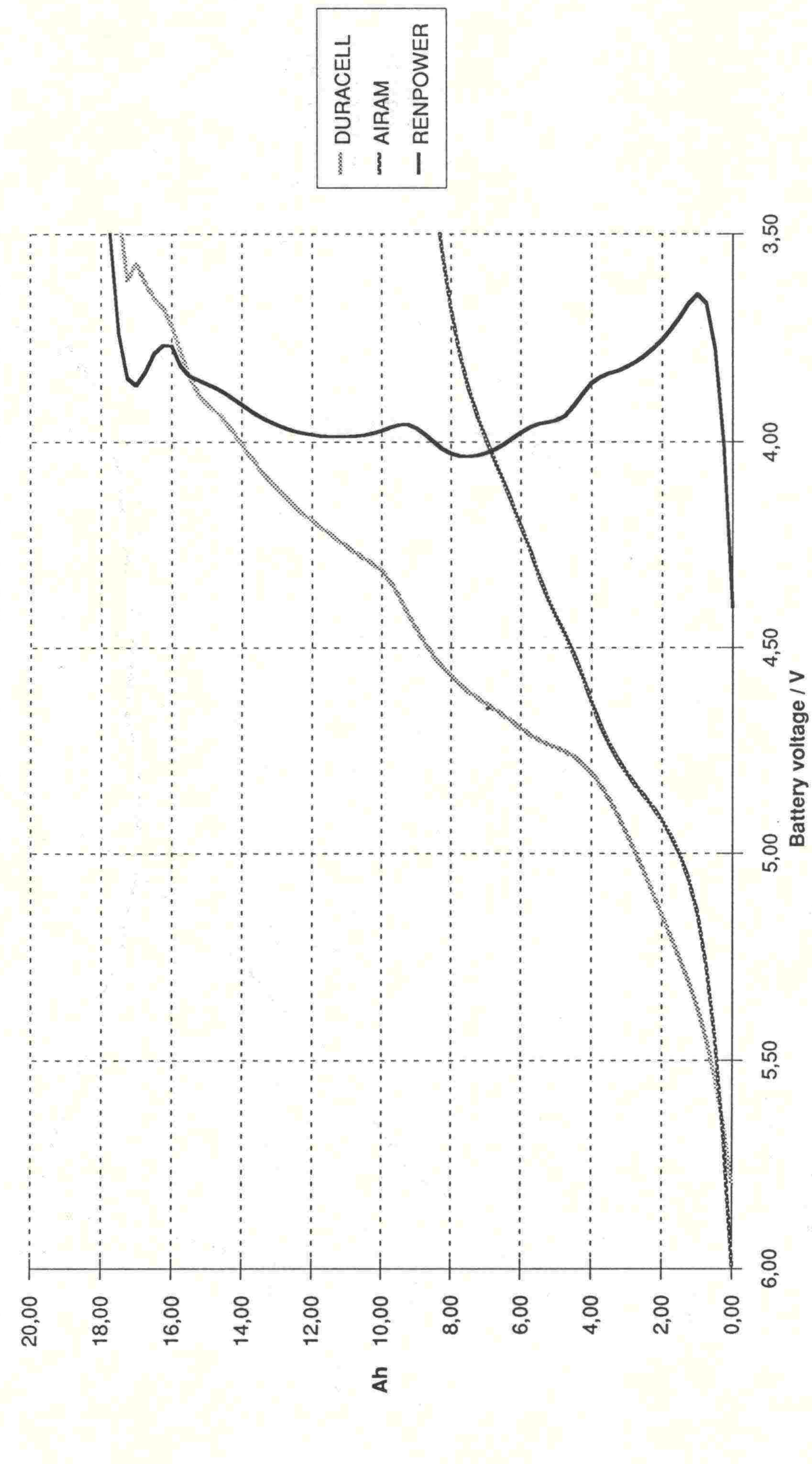



Ambient temperature: -10 °C
Battery type : IP5 6 V
U / V
6,00
5,50
5,00
4,50
4,00
3,50
0
5
10
15
20
25
Time / days
DURACELL
AIRAM
RENPOWER

APPENDIX 12

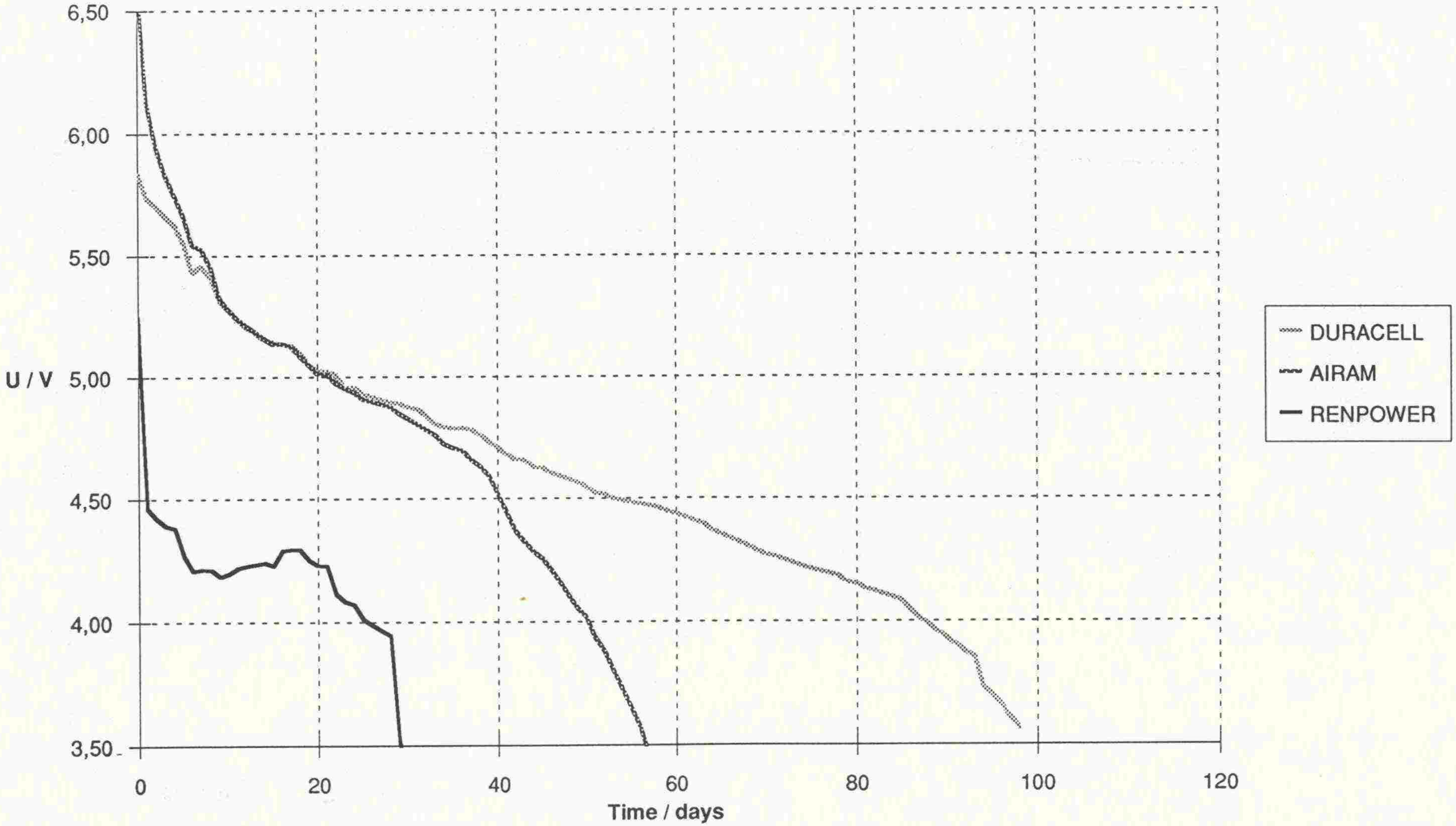
**Ambient temperature: -10 °C**

**Battery type : IP5 6 V**

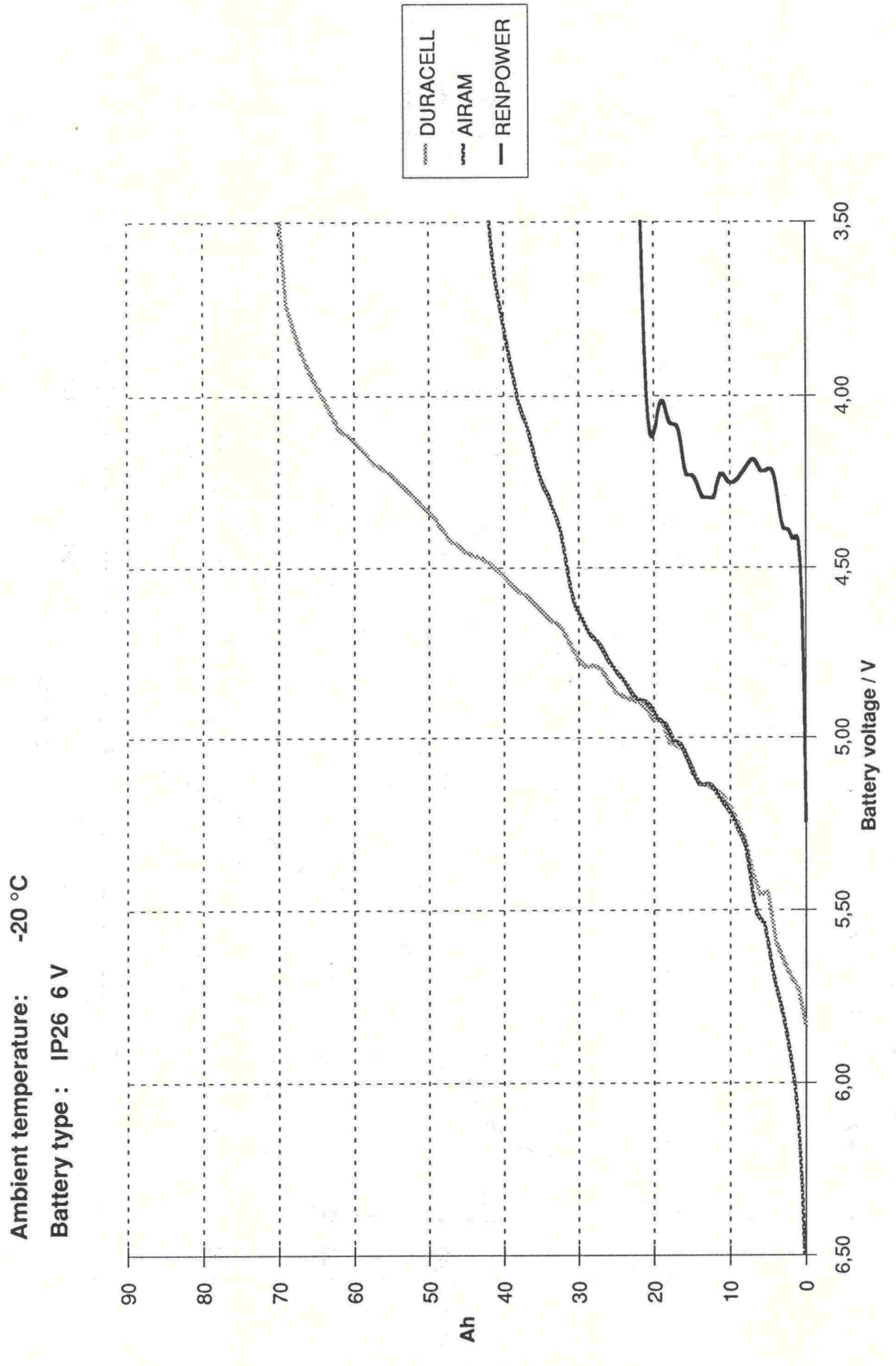


Ambient temperature: -20 °C

Battery type : IP26 6 V



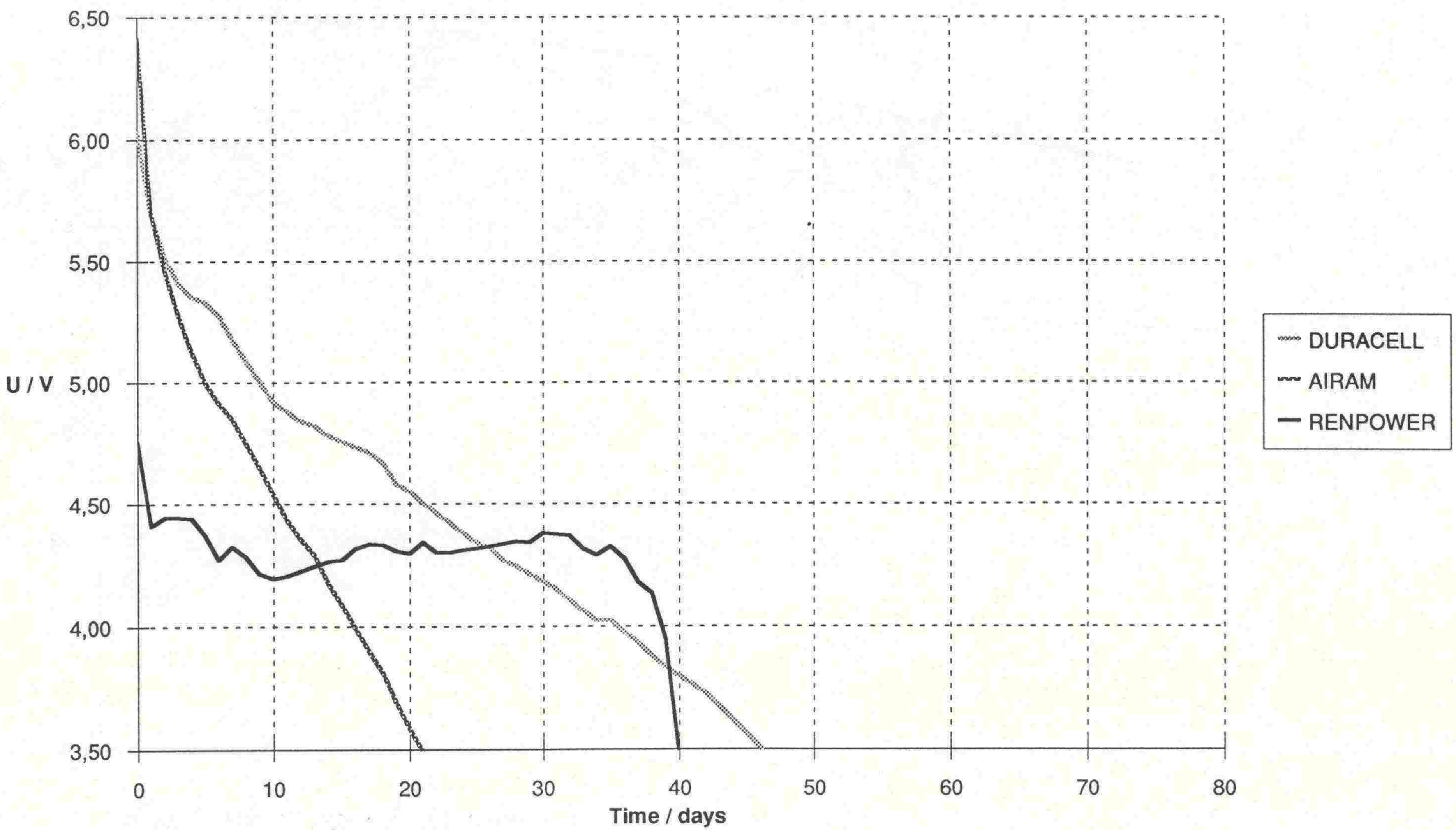
APPENDIX 14



Ambient temperature: -20 °C
Battery type : IP26 6 V
DURACELL
AIRAM
RENPOWER
Ah
90
80
70
60
50
40
30
20
10
0
6,50
6,00
5,50
5,00
4,50
4,00
3,50
Battery voltage / V

Ambient temperature: -20 °C

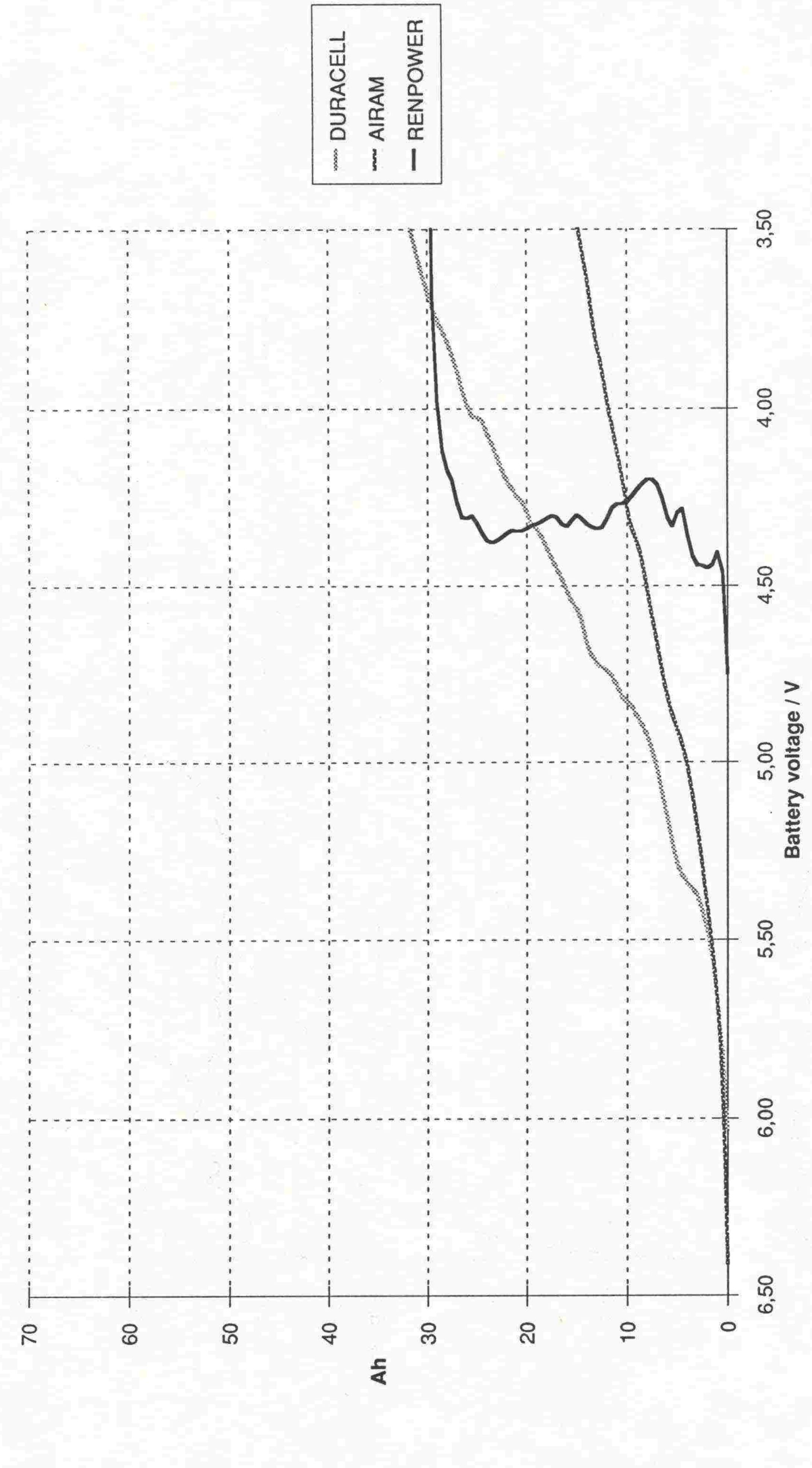
Battery type : IP5 6 V / 2 parallel



APPENDIX 16

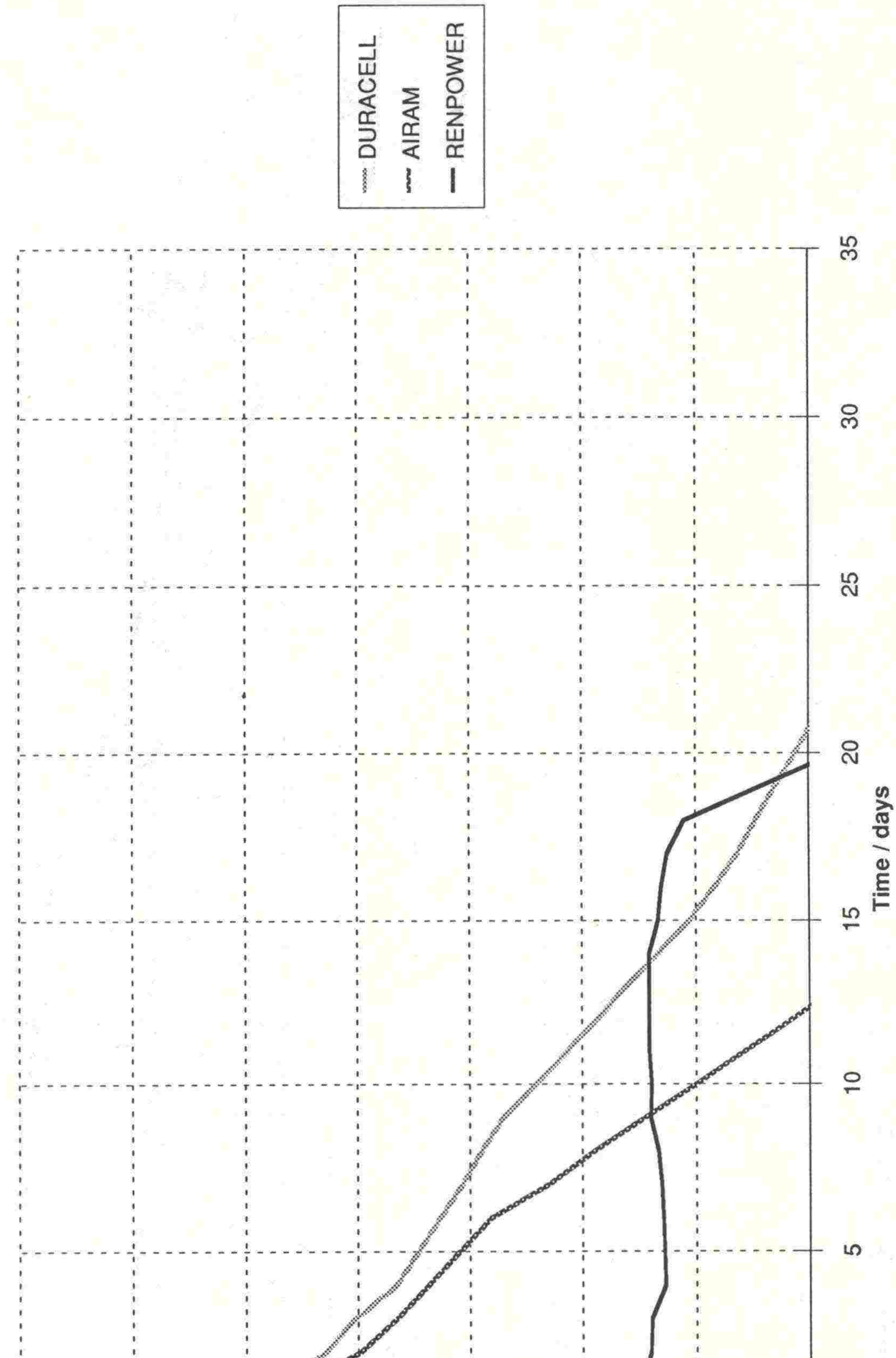
Ambient temperature: -20 °C

Battery type : IP5 6 V / 2 parallel



Ambient temperature: -20 °C

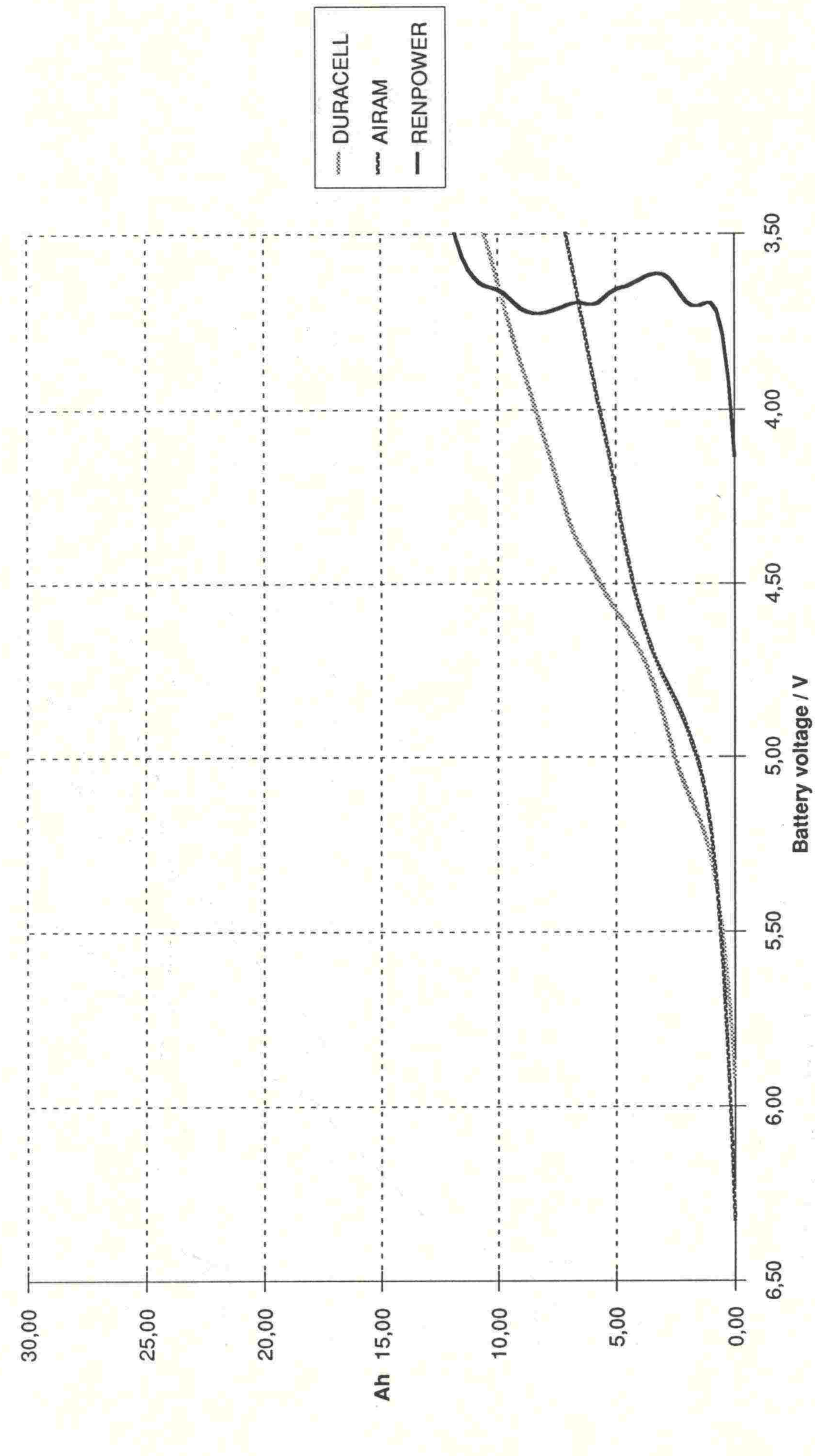
Battery type : IP5 6 V



APPENDIX 18

**Ambient temperature: -20 °C**

**Battery type : IP5 6 V**



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